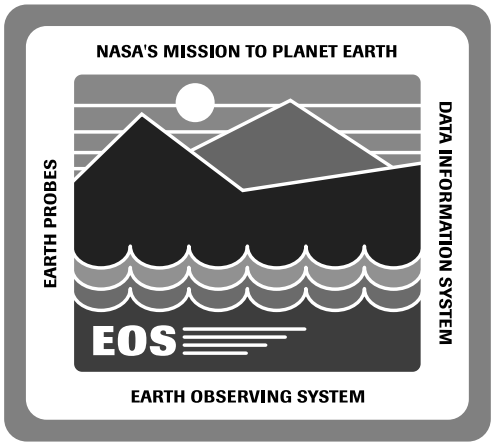
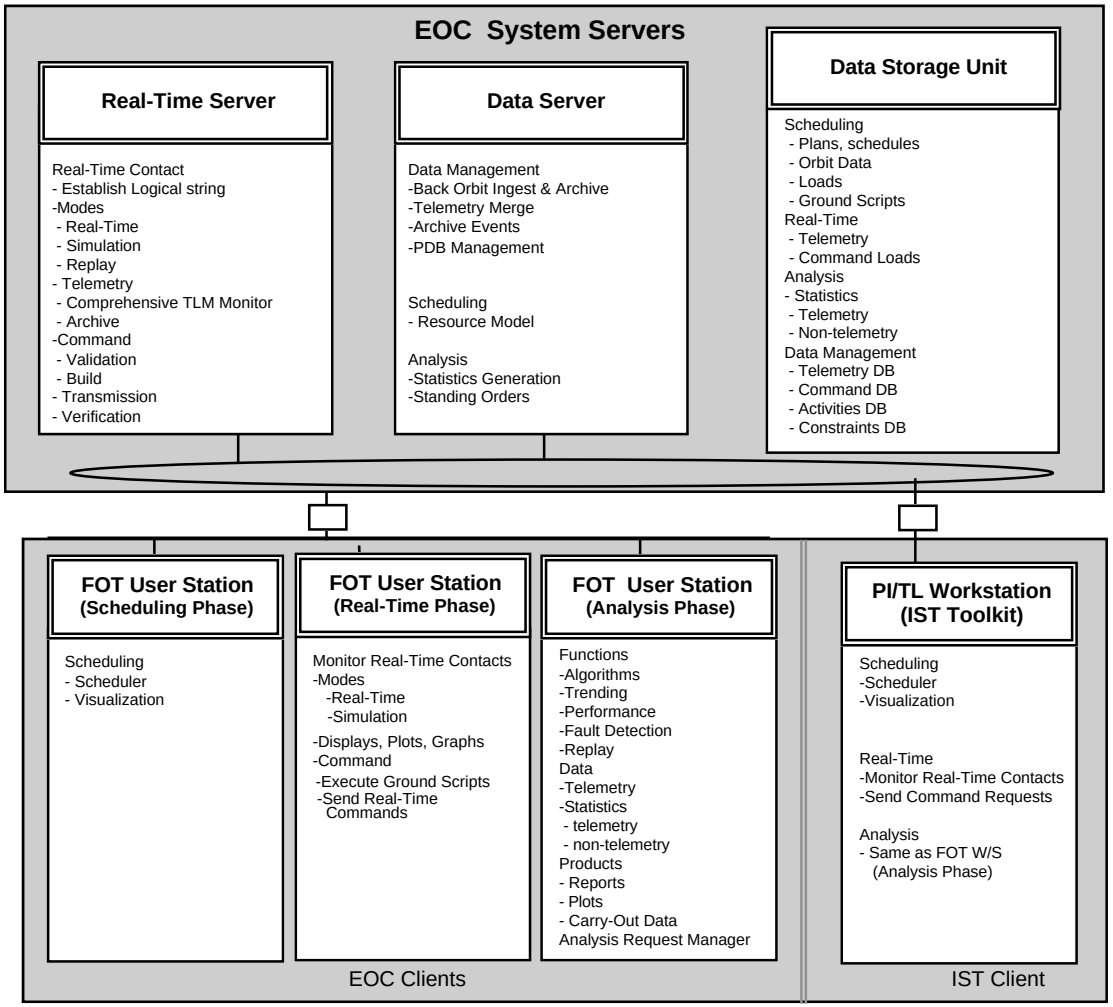


FOS Software Architecture

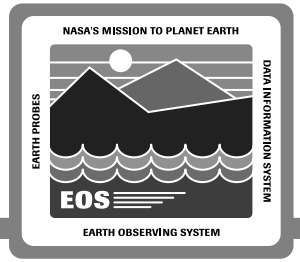
Jeff Cox

13 December 1994

FOS System Architecture



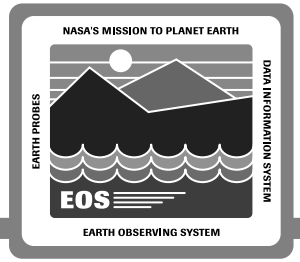
FOS System Architecture (cont.)



FOS software architecture is a mix of central and distributed processing

- **Centralized processing**
  - **FOS functional availability and maintainability**
  - **Autonomous processing**
    data driven and time triggered
  - **Process coupling**
    Telemetry and Command
- **Distributed processing**
  - **Reduce bottlenecks from centralization**
  - **Provide a robust and flexible system for the User**
  - **Exploit system resources**
    Network and CPU

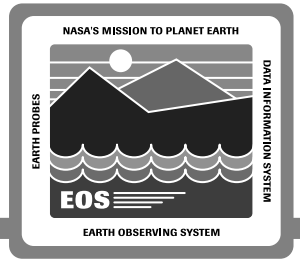
FOS Software Architecture



Key drivers

- **No single point of failure**
- **Provide quick response for FOT**
  - **1 minute to restore Real-time processing**
    30 second design goal
- **System control for the FOT**
  - **Man-in-the-loop at critical points**
    Failover, Load balancing, IST connectivity arbitration
- **Scalability for multiple mission support**
- **Common look and feel for Users**

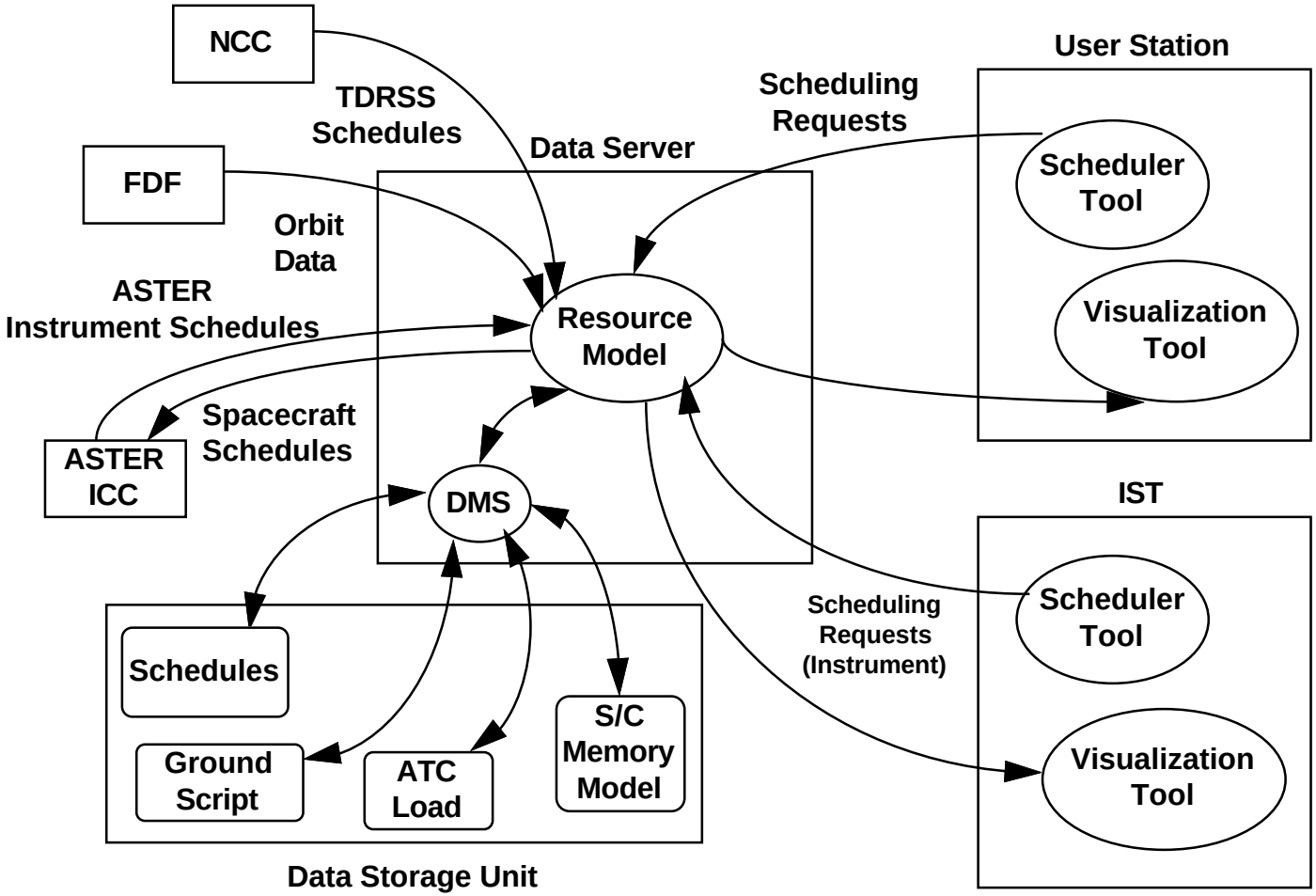
FOS Functionality



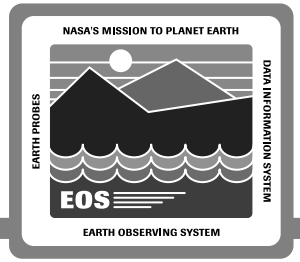
Function to Software Subsystem Mapping

Function	Software Subsystem
Scheduling	Planning & Scheduling Command Management
Real-time	Resource Management Real-time Contact Management Telemetry Command
Analysis	Analysis
Support	User Interface Data Management

Scheduling Architecture



Scheduling Architecture (cont.)



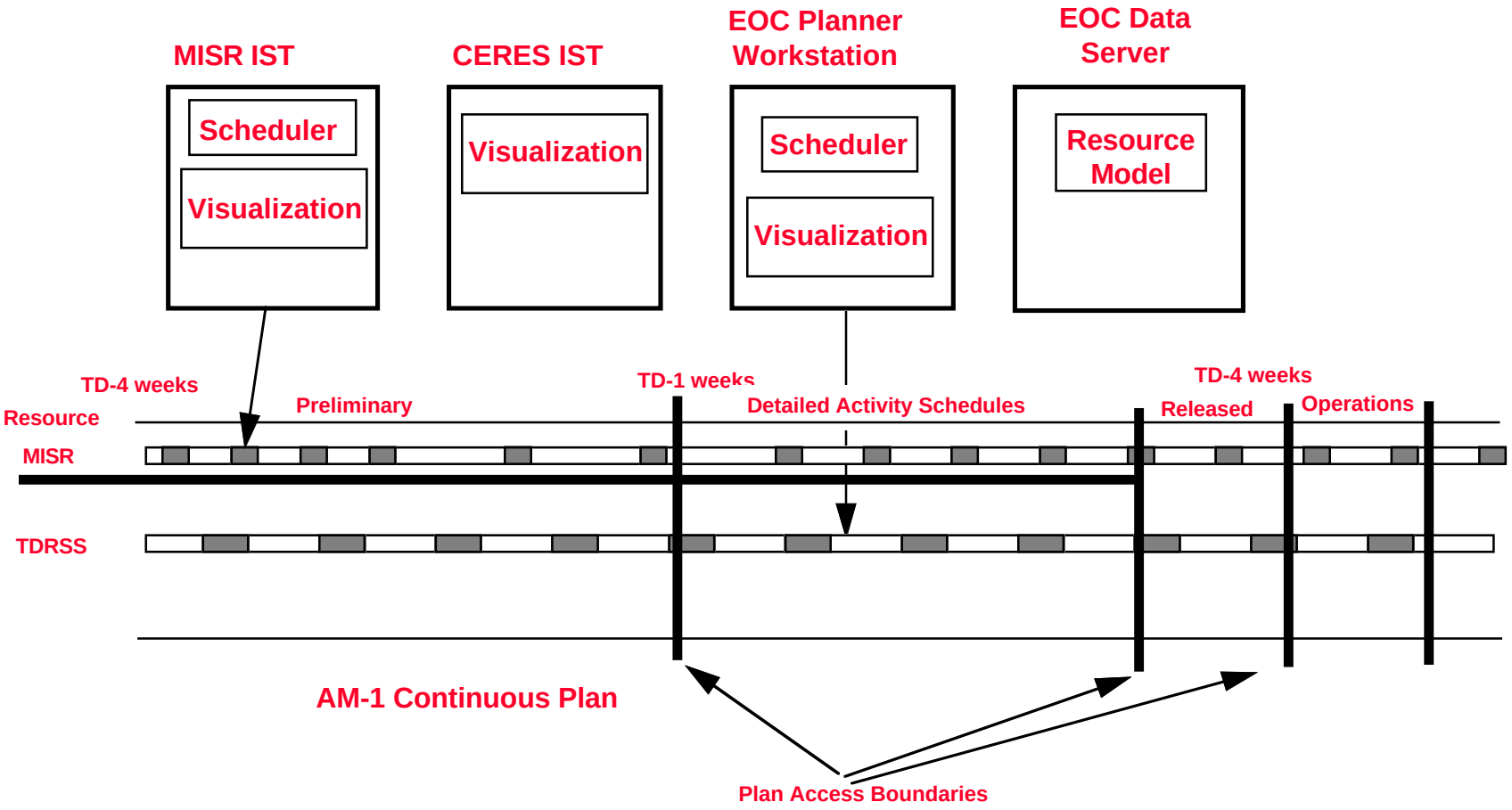
Comprised of two (2) software subsystems

- **Planning & Scheduling (P&S)**
- **Command Management (CMS)**

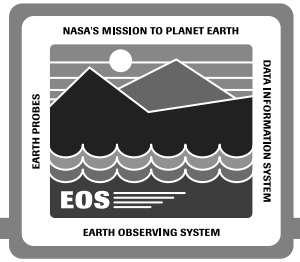
P&S and CMS integrated as part of seamless architecture

- **Resource Model**
- **Scheduler**
- **Visualization**

User Scheduling Access



Resource Model Architecture



Centralized Resource Model provides 24-hour scheduling functionality

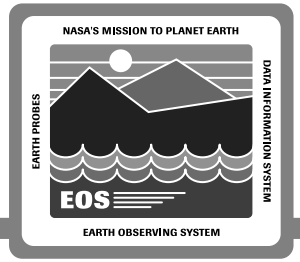
- **Supports geographically distributed users**
- **Provides autonomous processing**
  - **ASTER instrument schedules**
  - **TDRSS schedules and FDF orbit data**
  - **Management of Spacecraft Memory Model**

    Ground Reference Image

Manages the master copy of the Mission Plan to produce schedules, loads, and ground scripts

- **Users "check-out" sections of the schedule by "time" and "resource"**
  - **Check-out of section relieves scheduling collisions**
  - **Access by time releases section for further processing**
  - **Access by resource ensures exclusive control of scheduling**

Scheduling Tools Architecture



Tools are distributed to the User Station/IST

- **Improves scheduling performance**
- **Scalability**

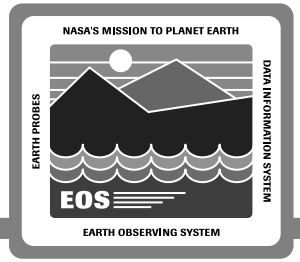
Scheduler Tool

- **Builds instrument and subsystem schedules**
- **Builds communication contact requests for recorder dumps**
- **Initiates ATC load and ground script generation**
- **Submits load uplink requests**

Visualization Tool

- **Provides EOC/IST global visibility into planned operations for all EOS instruments and subsystems**
- **Notifies users of scheduling constraints during the scheduling process**

Scheduling Design Highlights



Centralized Resource Model

- **Supports scheduling functions during all shifts**

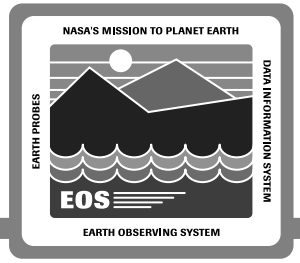
Distributed Tools

- **Improves scheduling performance**
- **Provides users with scheduling capability from any User Station/IST**

Schedule access method ensures exclusive control of resource

Design scales easily with addition of users

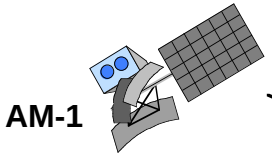
Real-time Architecture



Comprised of four (4) software subsystems

- **Resource Management (RMS)**
- **Telemetry (TLM)**
- **Command (CMD)**
- **Real-time Contact Management (RCM)**

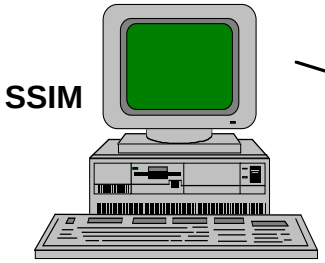
Logical String



Telemetry & Command
Logical Strings

EDOS/Ecom

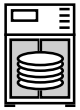
AM-1 Real-Time



ETS/Ecom

AM-1 Simulation

Data Storage Unit



Data Management

AM-1 Replay

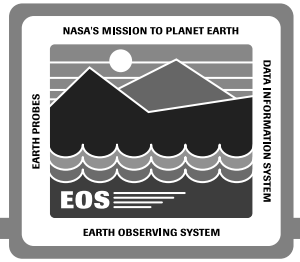
AM-1 Real-Time Contact
- Monitor AM-1 telemetry
- AM-1 commanding

AM-1 Real-Time Contact
- Monitor AM-1 telemetry
- Monitor AM-1 simulation

AM-1 Simulation
- Monitor AM-1 simulated telemetry
- Simulated AM-1 commanding

AM-1 Replay
- Monitor AM-1 historical telemetry

Logical String (cont.)



A collection of FOS resources supporting a specific process

- **Real-time contact**
- **Simulation**
- **Replay of historical telemetry data**

Provides FOT and IST users shared access to processing

- **Single user may access multiple logical strings**

Lifetime is determined by type of string

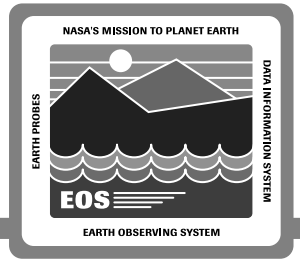
- **Real-time strings must be explicitly terminated**
- **Replay and Simulation strings terminate when last user disconnects**

String configuration is performed by users

- **User specifies RTS to support Real-time, Replay or Simulation logical string**
- **Default string configurations may be automated**

String management is across multiple RTS

Logical String Benefits

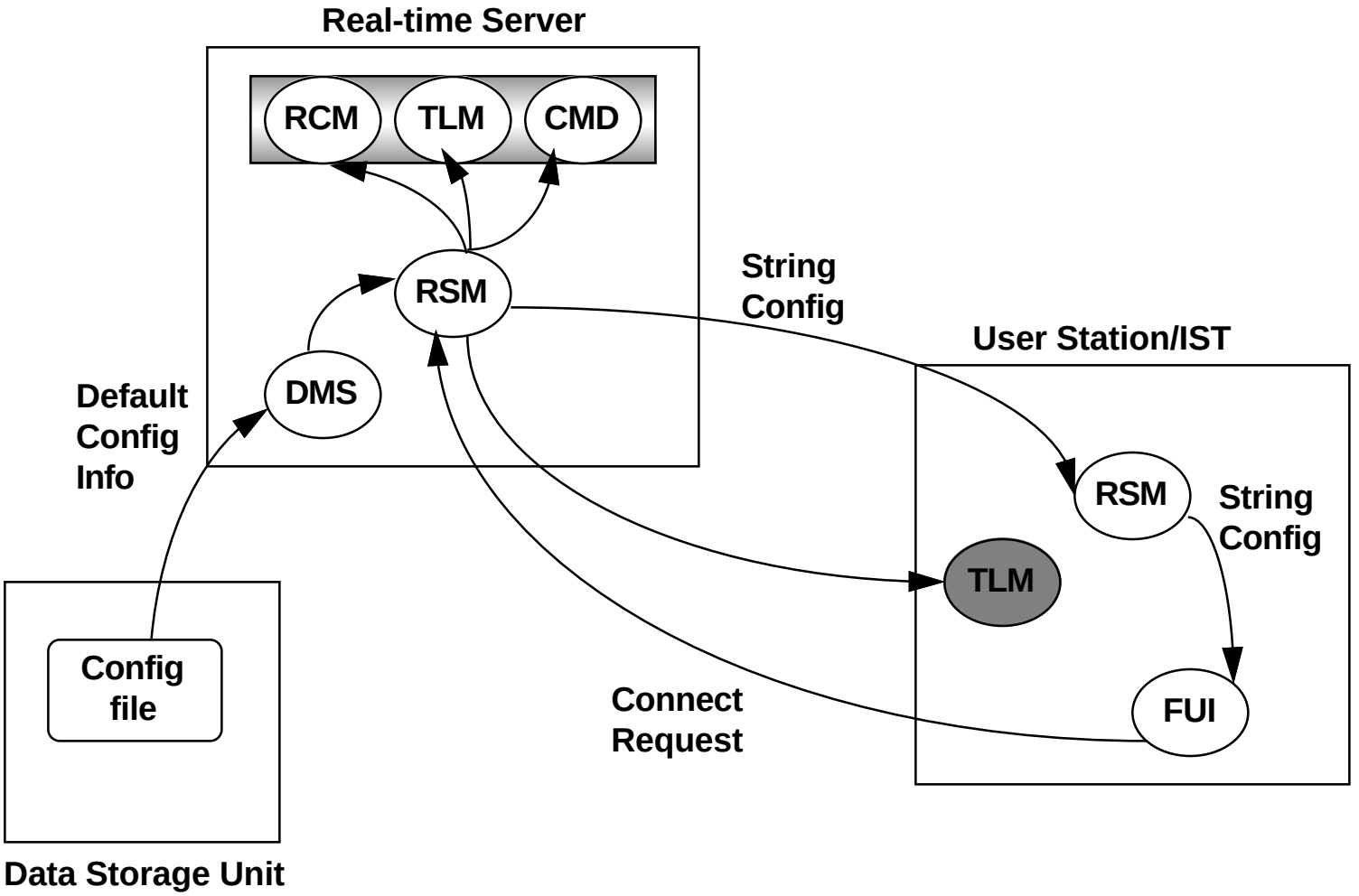


Logically separates real-time, simulation, and test processing

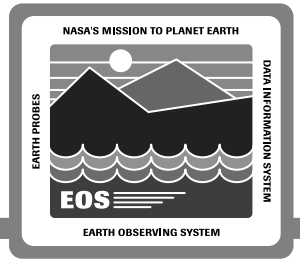
Facilitates failover of real-time contacts

- **Real-time logical string information is check-pointed for failover**

Resource Management Architecture



Resource Management Architecture (cont.)



Manages multiple logical strings on a Real-time Server

Ensures single point of commanding in the EOC

- **Grants command authority to FOT users**

Configures and manages FOS resources supporting real-time and analysis functions

Performs failover of Real-time contacts

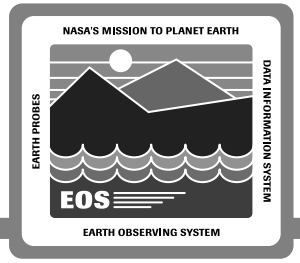
Manages Pool of IST connections to the EOC

- **IST connections available 24-hour a day**
  - **Process is automated**
- **Connection contention is arbitrated by FOT**

Provides FOT and IST users shared access to processing performed on the RTS

- **Existing logical strings are displayed to users**
  - **Users may join existing strings or create additional strings**
- **Provides EOC hardware and software status to users**

Resource Management Design Highlights



Single point of command guaranteed at the EOC

Logical strings provide FOT and IST users with shared access to processing

- **Users have view into FOS**

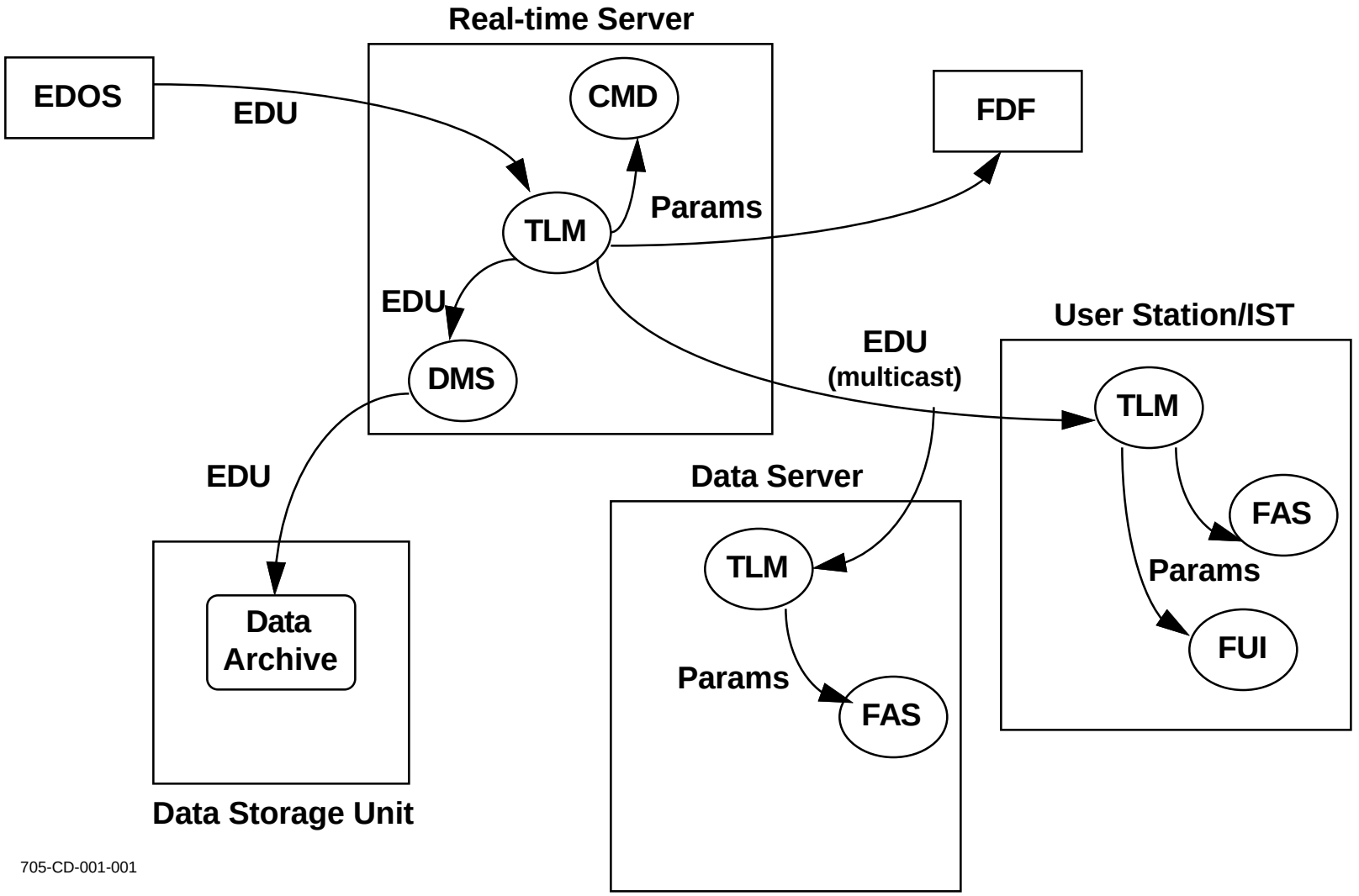
Automated configuration of logical strings

- **Ready to process real-time data autonomously**
  - **Connection by FOT or IST user is not required**

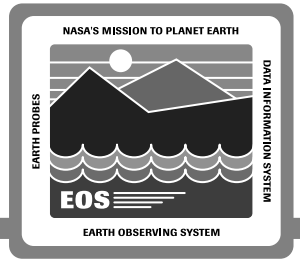
Manages IST connections to the EOC

Design scales well with addition of hardware and missions

Telemetry Architecture



Telemetry Architecture (cont.)



A single telemetry subsystem can serve multiple applications simultaneously

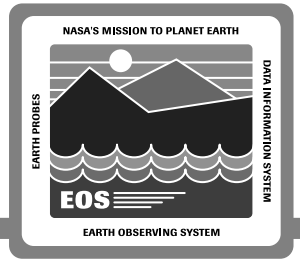
- **Applications request a subset of parameters being decommutated**
- **The telemetry subsystem serves parameters synchronously**

  (e.g., all values of a super commutated parameter are delivered)

Telemetry processing is distributed across FOS hardware

- **Real-time Server (RTS)**
- **User Station/IST**
- **Data Server (DS)**

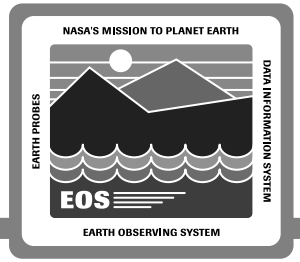
Telemetry Architecture (cont.)



RTS telemetry processing

- **EDUs received are stored for historical replay**
  - **EDOS baseline delivers EDUs to one destination**
- **EDUs are multicast to telemetry processes at User Station/IST**
  - **Multicasting is a network message addressing technique**
    - **One message is sent over the network to multiple nodes**
      - **Message is sent to a "Group Address"**
  - **Multicasting capability provided by ECS CSMS**
  - **Multicasting used successfully in heritage systems reducing server load and network bandwidth utilization**
    - **New hosts are added to the Group without increasing server load**
    - **Sending node sends only one message**

Telemetry Architecture (cont.)



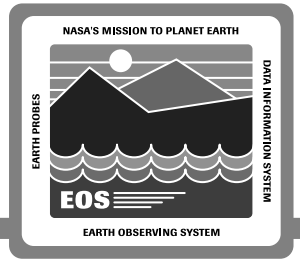
RTS telemetry processing (cont.)

- **Provides comprehensive telemetry monitoring**
  - **Total parameter processing**

    Processes all telemetry parameters in the data stream
  - **Generates Critical alarms**

    Produces complete historical trace for each contact
  - **Allows users with ground control authority to set temporary limits**
- **Serves telemetry parameters to the Command subsystem**
  - **Command uses telemetry values for command validation and verification**

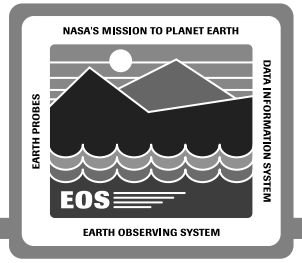
Telemetry Architecture (cont.)



User Station/IST telemetry processing

- **Mirrored configuration performs identical processing to the RTS**
  - **Total parameter processing**
  - **Controlled by the RTS Comprehensive Telemetry Monitor**
    - **Temporary limit definitions are received via multicast**
- **Tailored configuration allows user to process a subset of the data stream**
  - **Tailored Telemetry processing**
    - **Selective parameter processing**
    - **Local definition of temporary limits controlled by user**
  - **Reduces User Station/IST processor load**
  - **Alarms remain local to the User Station/IST**

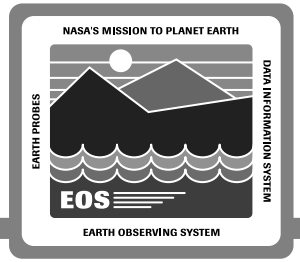
Telemetry Architecture (cont.)



Data Server telemetry processing

- **Solid State Recorder monitoring**
  - **Real-time analysis on a subset of data**
- **Automatic statistics generation**

Telemetry Design Highlights



One architecture for FOS processing

- **Real-time and analysis processes can share the same data on the same processor**
  - **Analysis processing can be performed in real-time**

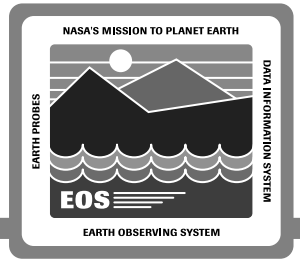
All parameter values are provided

- **Real-time processing is provided parameter data at the same granularity as for analysis**

Selective parameter decommutation is available in real-time and off-line

- **Processor load is lower than with comprehensive decommutation**
- **User can monitor data selectively from multiple sources**

Telemetry Design Highlights (cont.)



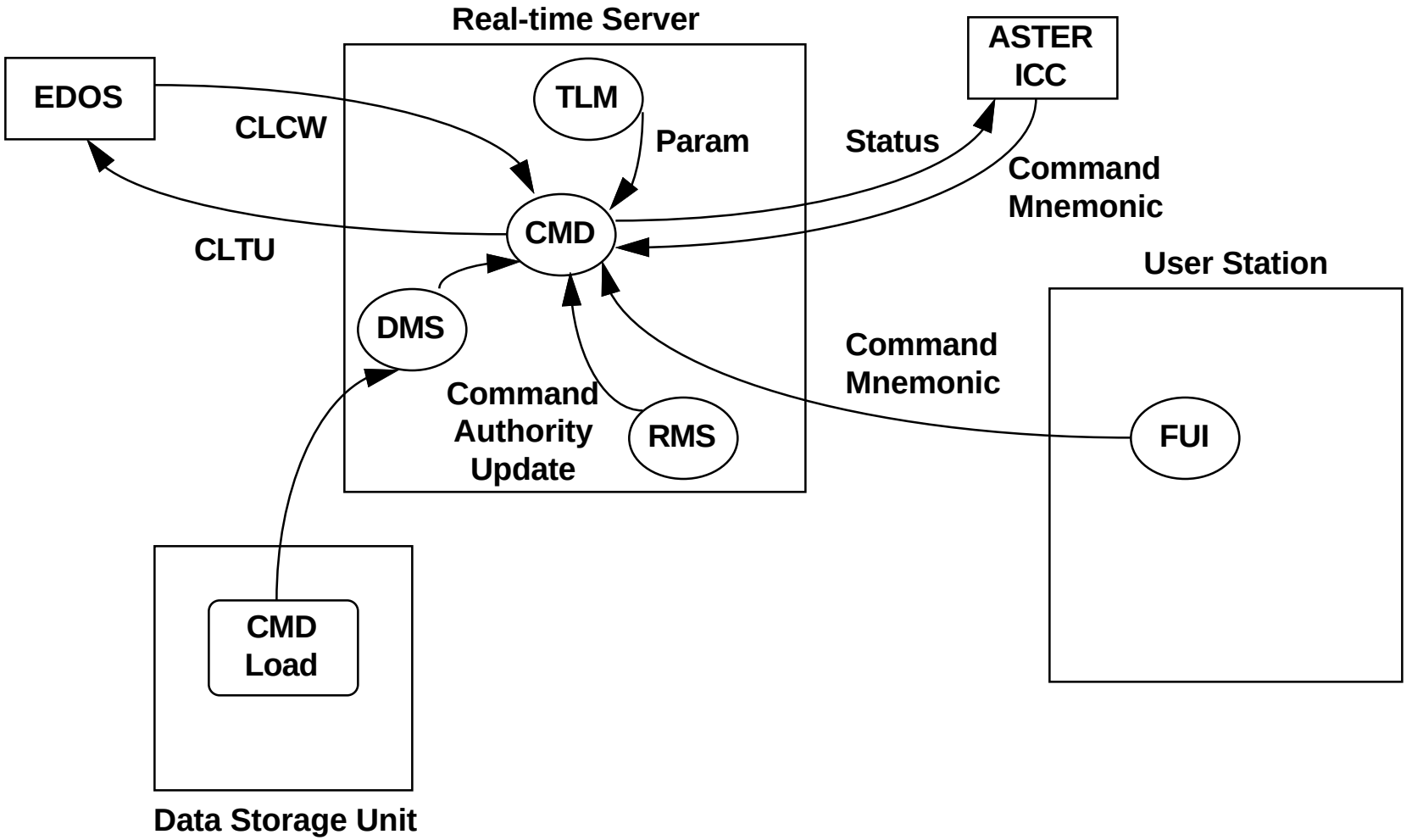
Distribution of EDU processing to the User Station/IST and DS

- **Provides scalability due to EDU processing on all hardware platforms**
  - **Additional positions can be added without increasing load on the RTS due to multicasting**
  - **Lower bandwidth utilization due to distribution of raw data versus processed data**

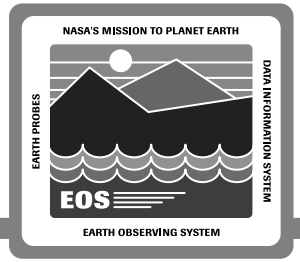
Distribution of telemetry parameter processing to the User Station/IST and Data Server

- **Telemetry parameter processing is performed locally**
  - **Multiple telemetry streams may be processed on the same processor**
  - **Additional applications receiving telemetry values affects local processing performance**

Command Architecture



Command Architecture (cont.)



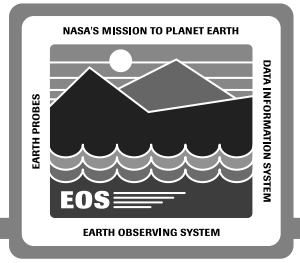
Performs uplink of commands

- **Real-time commands issued by FOT or ASTER ICC**
  - **ASTER ICC commanding privilege**
    - **Requires coordination with FOT**
    - **FOT grants ASTER ICC the authority to issue ASTER commands**
    - **FOT maintains the capability to unconditionally regain command**
- **Command loads generated by CMS**

Validates user command authority

- **Each real-time command directive is validated**
- **Limits ASTER ICC commanding to their instrument**
- **Command authority is managed and updated by the RMS**

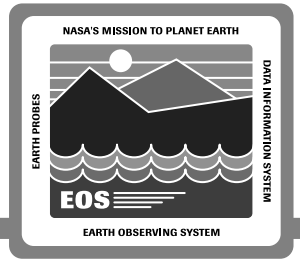
Command Architecture (cont.)



Maintains CCSDS telecommand protocol integrity

- **Backup RTS runs a hot backup CMD subsystem**
  - **Command directives are fed to each CMD subsystem**
  - **CLCW is forwarded to backup CMD subsystem**
- **Backup string is required to maintain COP protocol**

Command Architecture (cont.)



Verifies command receipt and execution

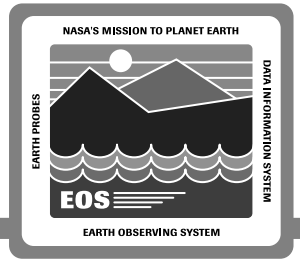
- **Commands issued during a real-time contact are always verified**
  - **COP protocol provides receipt verification**
  - **Verification in telemetry is by discrete parameter**

    Telemetry verification is database defined
- **ASTER ICC receives command verification status whenever an ASTER instrument command is issued from the ground**
- **Verification of commands currently executing on board the spacecraft is possible when telemetry is present during a contact**

Provides historical trace of command activity during contact

- **Event messages are generated for every command processed**

Command Design Highlights



Single point of command authority

Real-time commands are validated

ASTER ICC is restricted to commanding only their instrument

ASTER ICC is notified of commands issued to their instrument

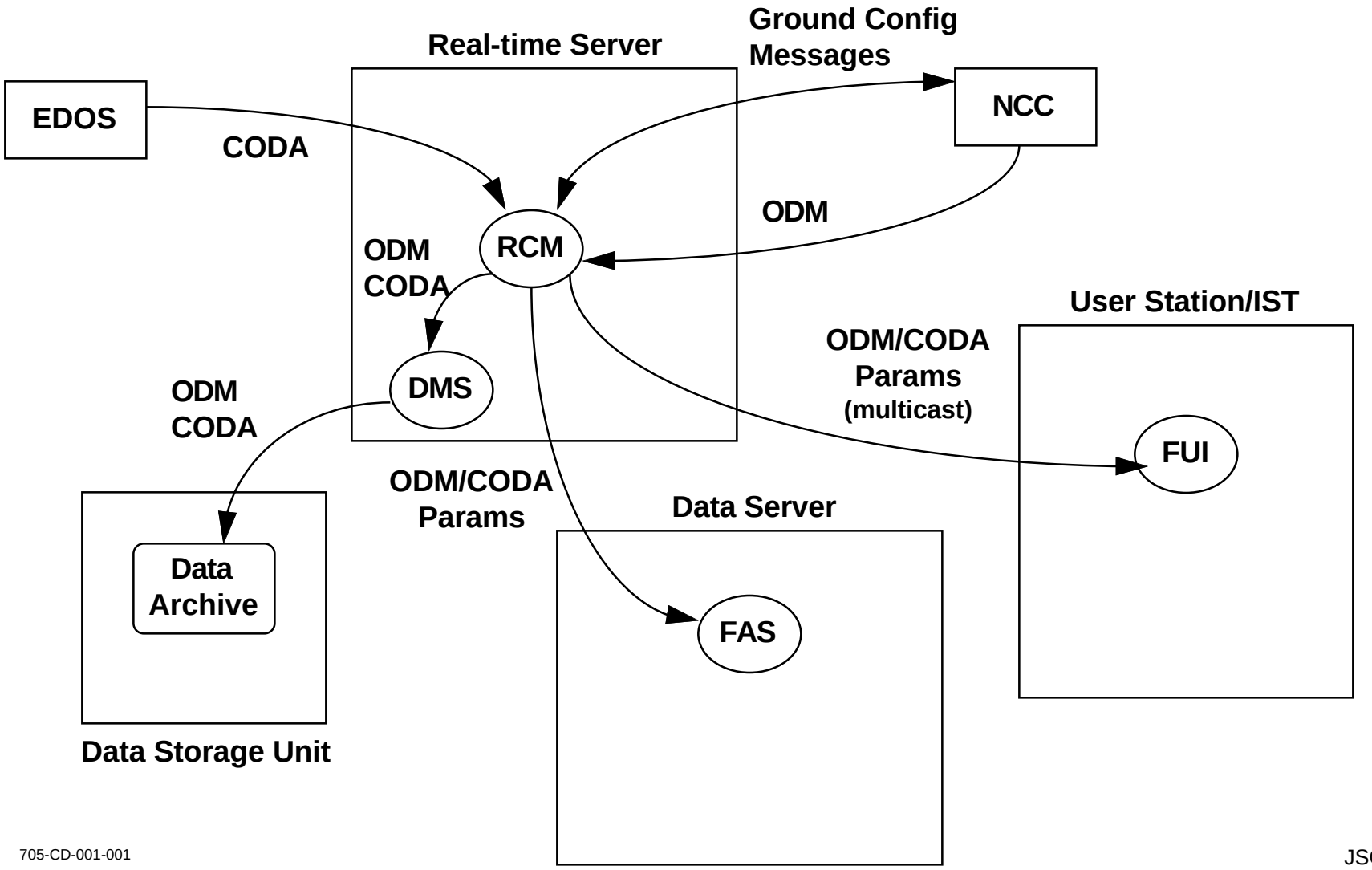
- **Command may originate within the EOC or at the ASTER ICC**

CCSDS telecommand protocol integrity is maintained

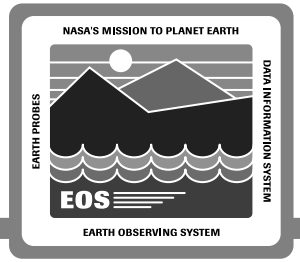
- **Parallel string processes all commands and CLCWs**

Historical trace of command activity and verification status maintained

Real-time Contact Management Architecture



Real-time Contact Management Architecture (cont.)



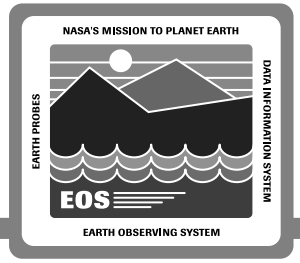
Configures the ground system in support of a spacecraft contact

Processes NCC performance data, EDOS accounting messages, and DSN monitor blocks

- **Serves data to Analysis for statistics processing**
- **Serves data to User Interface for display to users**
  - **Multicasts data to reduce network load**

Stores NCC, EDOS, and DSN data as received to support FOT trouble shooting

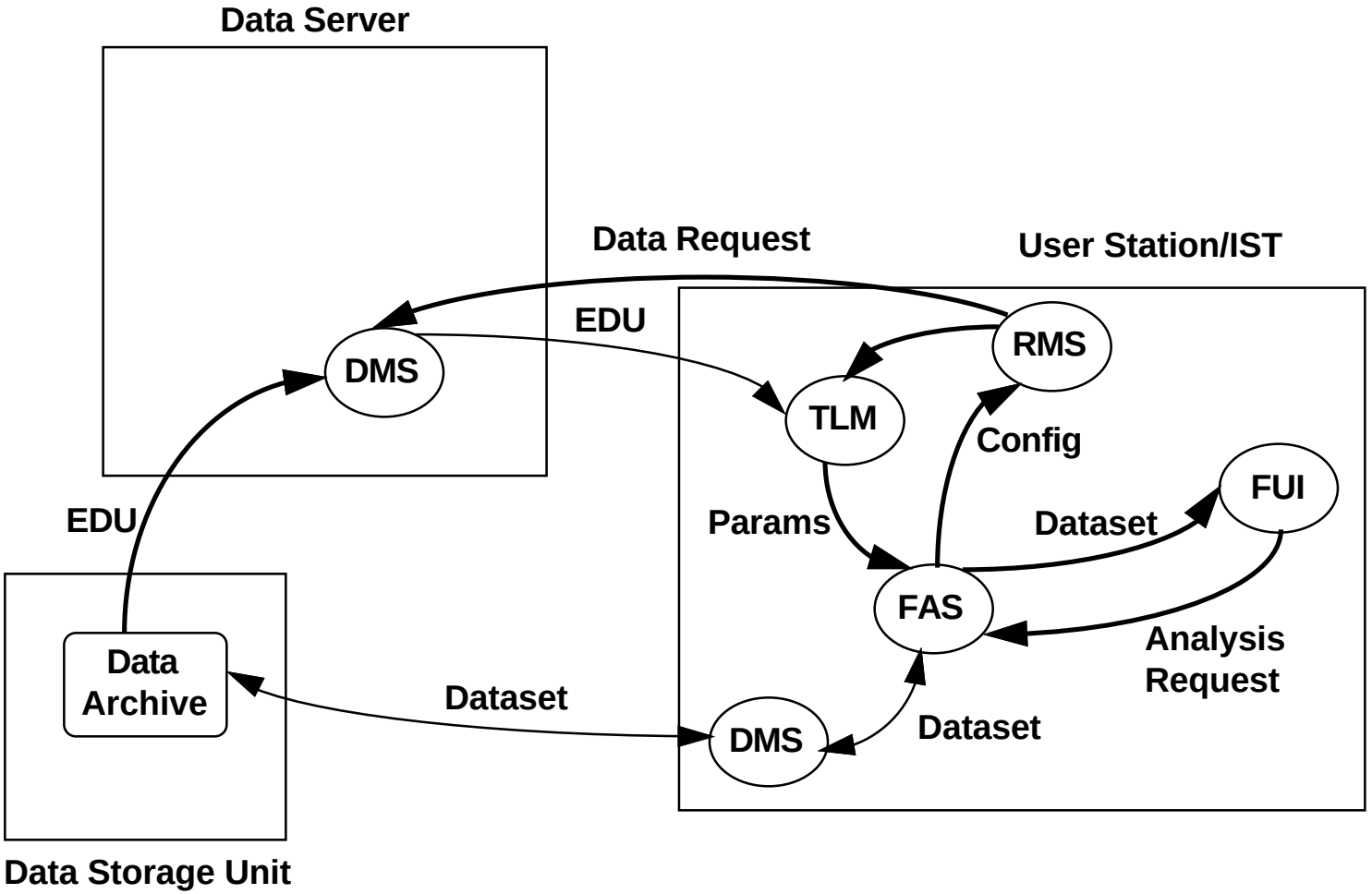
Real-time Contact Management Design Highlights



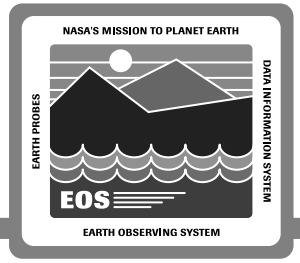
Provides NCC, EDOS, and DSN parameters to Analysis in real-time for statistics processing

Raw NCC, EDOS, and DSN data stored for troubleshooting

Analysis Request Architecture



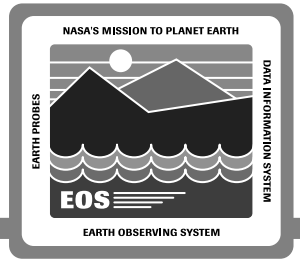
Analysis Request Architecture (cont.)



Requests are managed and processed locally at the User Station/IST

- **User can prioritize analysis requests queued for processing**
  - **Queueing provides throttling mechanism**
- **Off-line analysis requests process data at a minimum of twelve (12) times the real-time telemetry rate**
  - **Off-line analysis may execute on the same User Station/IST that is monitoring a real-time contact**
- **User may configure analysis processing to support a real-time contact**
  - **Data interface is same**
  - **Real-time data rates are less than off-line processing rates**

Analysis Request Architecture (cont.)



Analysis requests produce a "dataset "

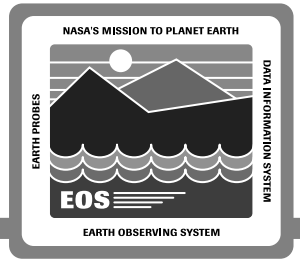
- **A dataset is an interim analysis data product from which multiple analysis output products may be generated**
  - **Dataset is standard input to produce analysis graphs, spreadsheets, tables, and reports**
- **Datasets may be saved for reprocessing by the analysis subsystem**

User may specify "carry-out" data for an analysis request

- **Carry-out data is an ASCII file containing an analysis product**

Analysis processing supports user defined algorithms

Analysis Request Architecture Design Highlights

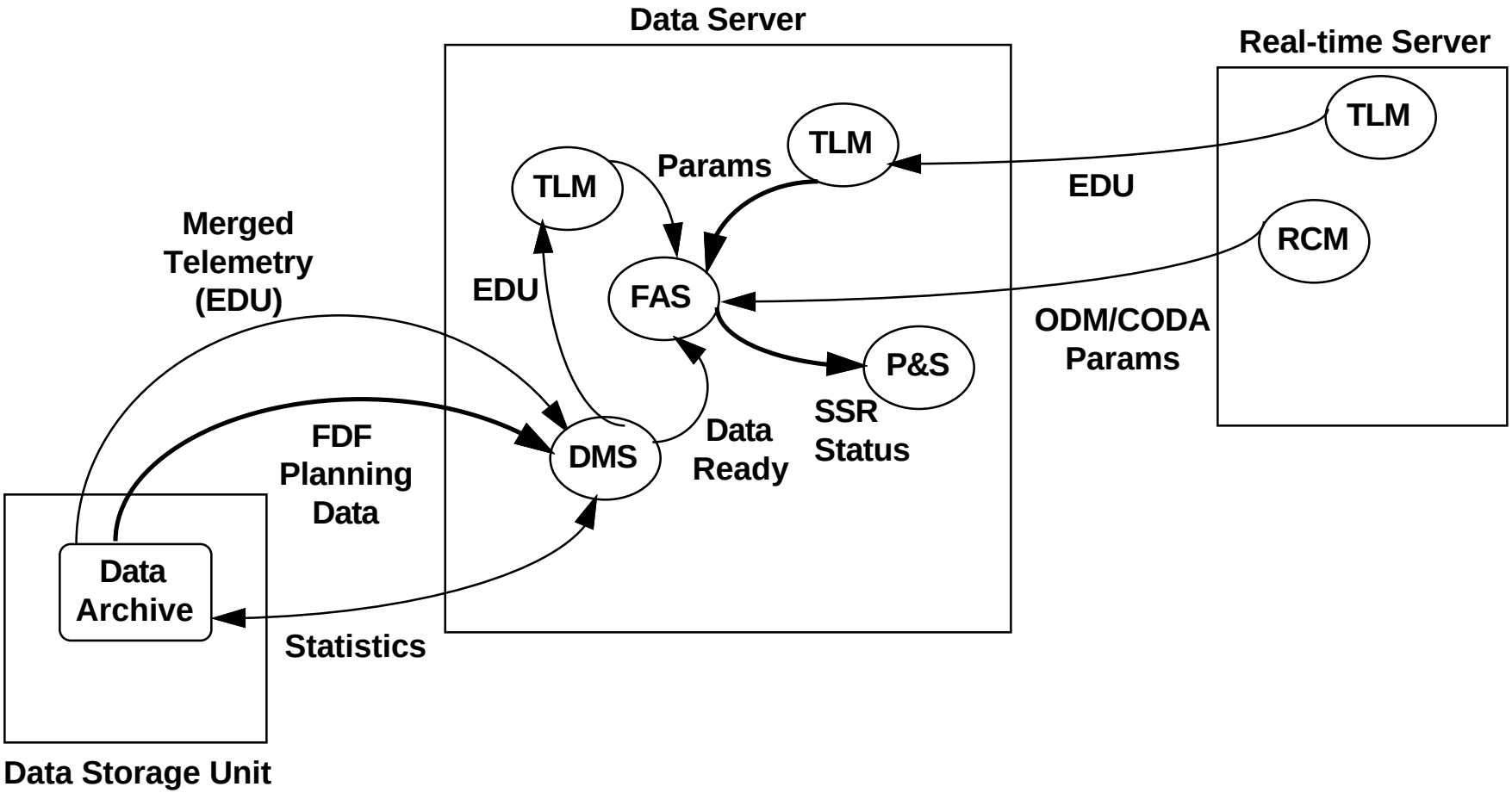


User requests are processed on the User Station/IST

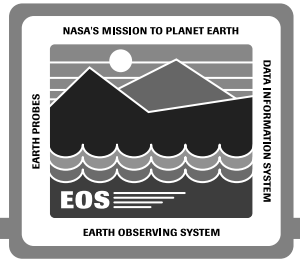
- **Provides user control and monitoring of local request processing**
- **Analysis products are produced from datasets**
  - **Datasets may be stored for reprocessing by analysis subsystem**
  - **Same dataset may be used to produce multiple analysis products**

    Reduces load on network, servers, and User Station/IST
- **Carry-out data allows users to reprocess analysis data outside of the IST Toolkit environment**
- **Analysis functions may be performed in parallel to real-time functions**
  - **Provides analysis support during real-time contacts**

Analysis Automated Architecture



Analysis Automated Architecture (cont.)



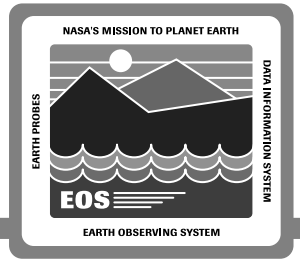
Performs automated statistics computation on the Data Server

- **Telemetry statistics computed from the DMS merged telemetry**
  - **DMS notifies analysis that data is ready for processing**
- **FDF Planning Data statistics**
  - **DMS notifies analysis that data is ready for processing**
- **EDOS CODA and NCC ODM statistics are processed in real-time**
  - **Data is received from the Real-time Contact Management subsystem**

Processes “Standing Orders” for user specified analysis products

- **Standing Order is a time triggered request for analysis processing**
- **A method for users to schedule the production of analysis products on a timed interval**
- **Standing Orders are processed on the Data Server and are managed by the User Interface subsystem**

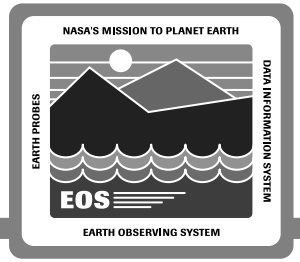
Analysis Automated Architecture (cont.)



Solid State Recorder monitoring

- **Performed in real-time during recorder dumps**
- **Processes telemetry data, and EDOS/NCC status messages**
  - **Detects faults and provides recorder data recovery recommendations to FOT to maximize use of contact period**
- **Provides status to P&S and User Interface for display**
  - **Status is used to maintain an accurate SSR model for buffer management**

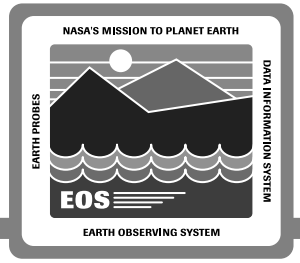
Analysis Automated Architecture Design Highlights



Centralized processing supports analysis functions during all shifts

- **Data driven statistics processing**
  - **Ensures all data is processed**
  - **Provides prompt access for users**
- **Supports Standing Order processing**
  - **Time triggered processing**
- **Solid State Recorder monitoring**
  - **Assists FOT in determining best use of remaining contact to prevent data loss**
  - **Provides automated notification to P&S regarding status for buffer management**

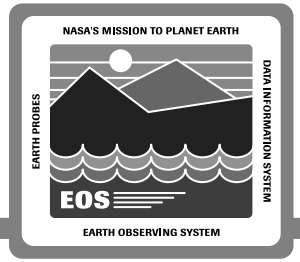
Support Architecture



Comprised of two (2) FOS software subsystems and CSMS services

- **User Interface (FUI)**
- **Data Management (DMS)**
- **CSMS**

Support Architecture Design Highlights



User Interface

- **Common look and feel**

Data Management

- **Manages all data generated within the EOC (e.g., Databases, Events, Analysis data products)**
- **Merge of back-orbit data is performed immediately after successful receipt**
  - **Statistics are performed on data as soon as it is available**